



Improving X-Ray Optics Through Differential Deposition

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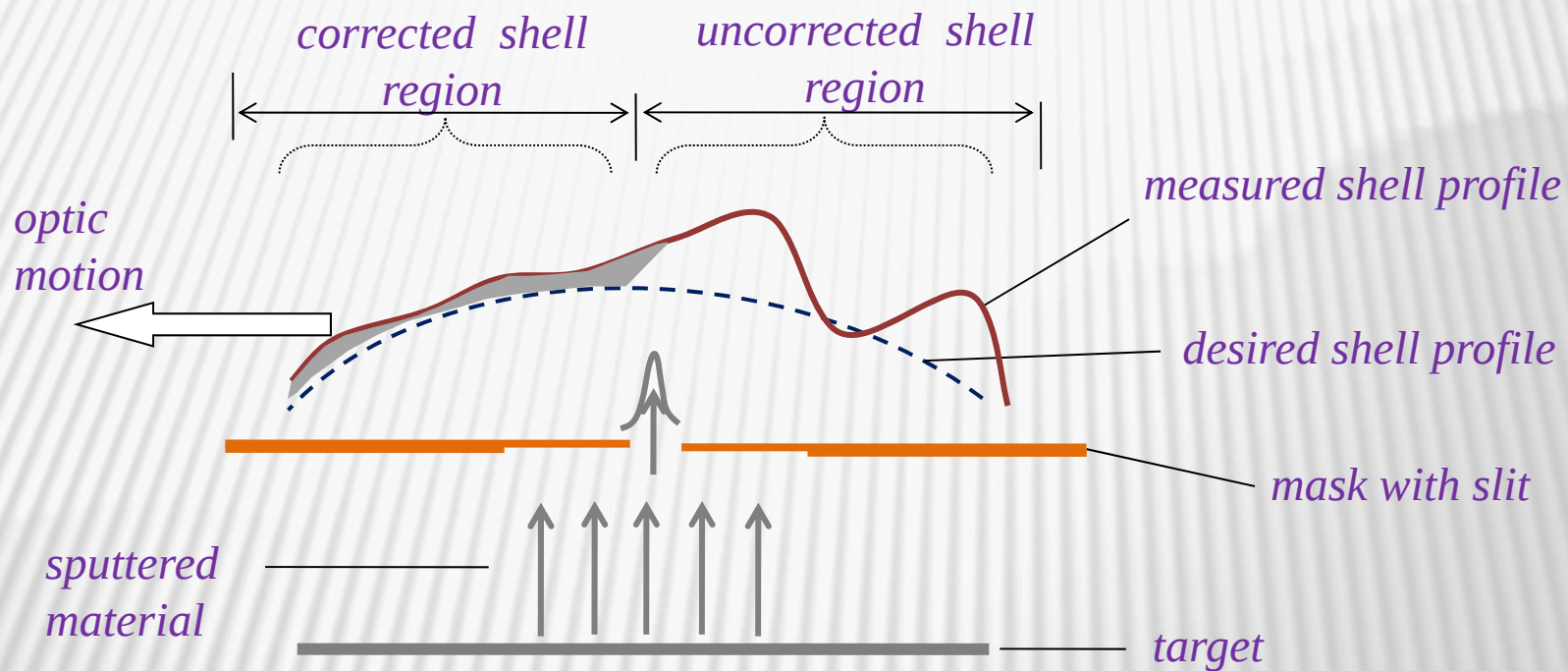


Differential deposition

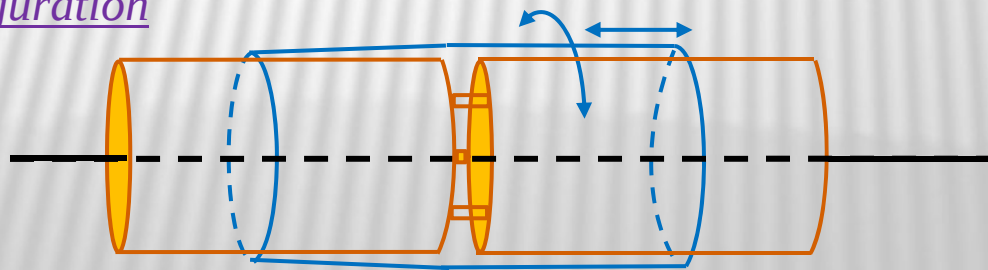
- What
 - Differential deposition is a technique for correcting figure errors in optics
- How
 - Use physical vapor deposition to selectively deposit material on the mirror surface to smooth out figure imperfections
- Why
 - Can be used on any type of optic, mounted or unmounted
 - Can be used to correct a wide range of spatial errors
 - Technique has been used by various groups working on synchrotron optics to achieve sub- μ radian-level slope errors



Addressing profile deviations through differential deposition

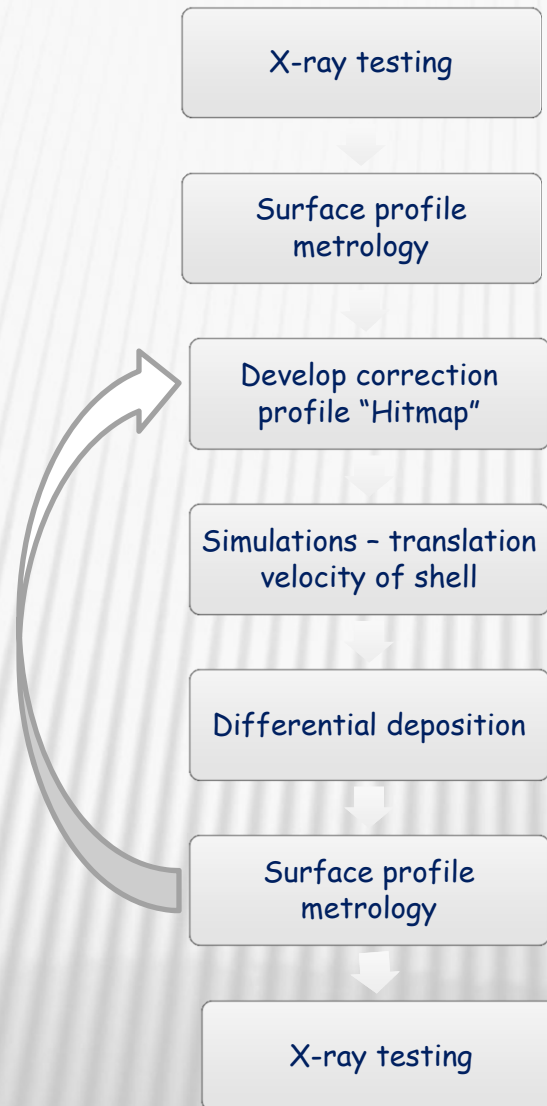


Full Shell Configuration

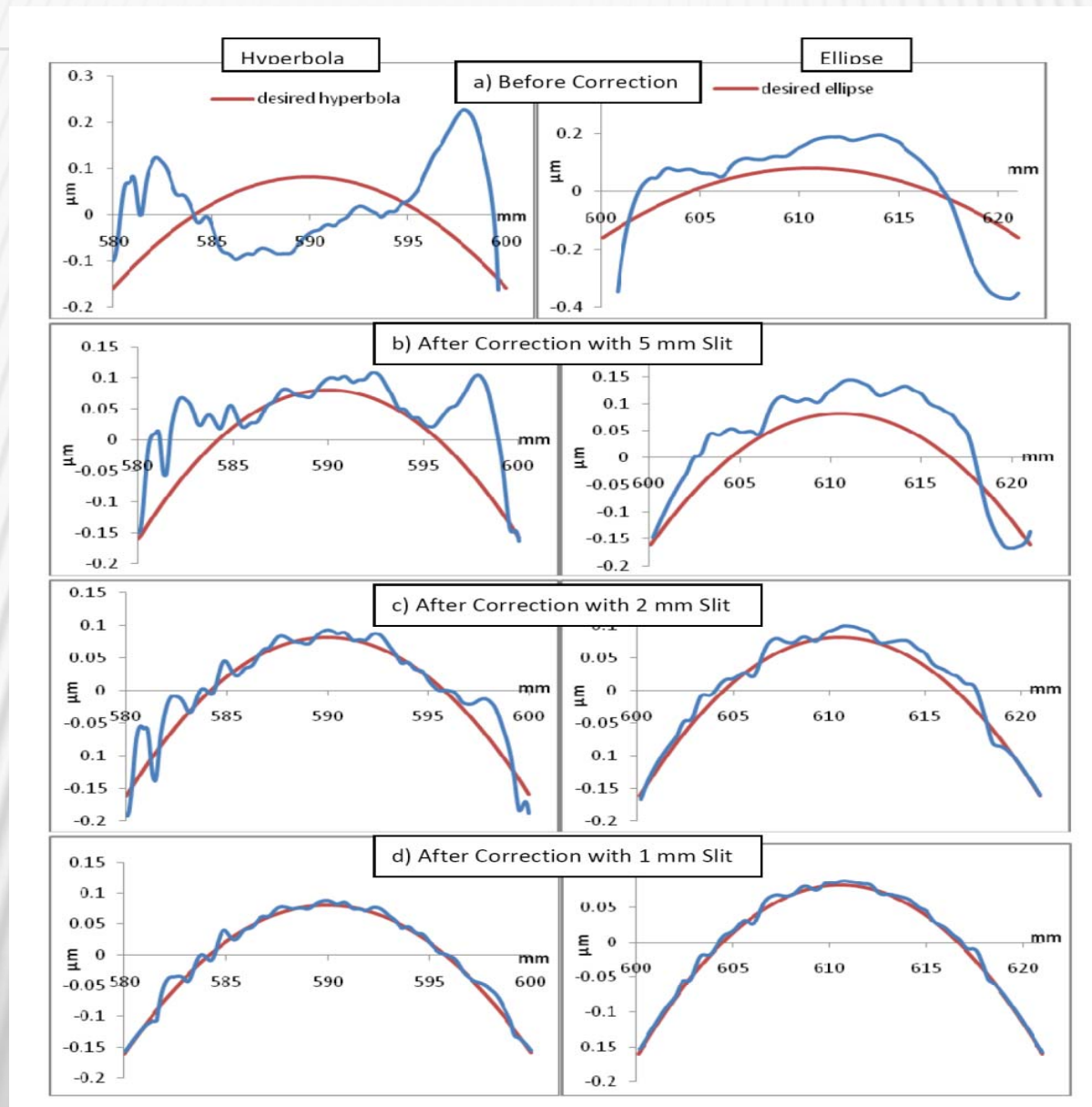




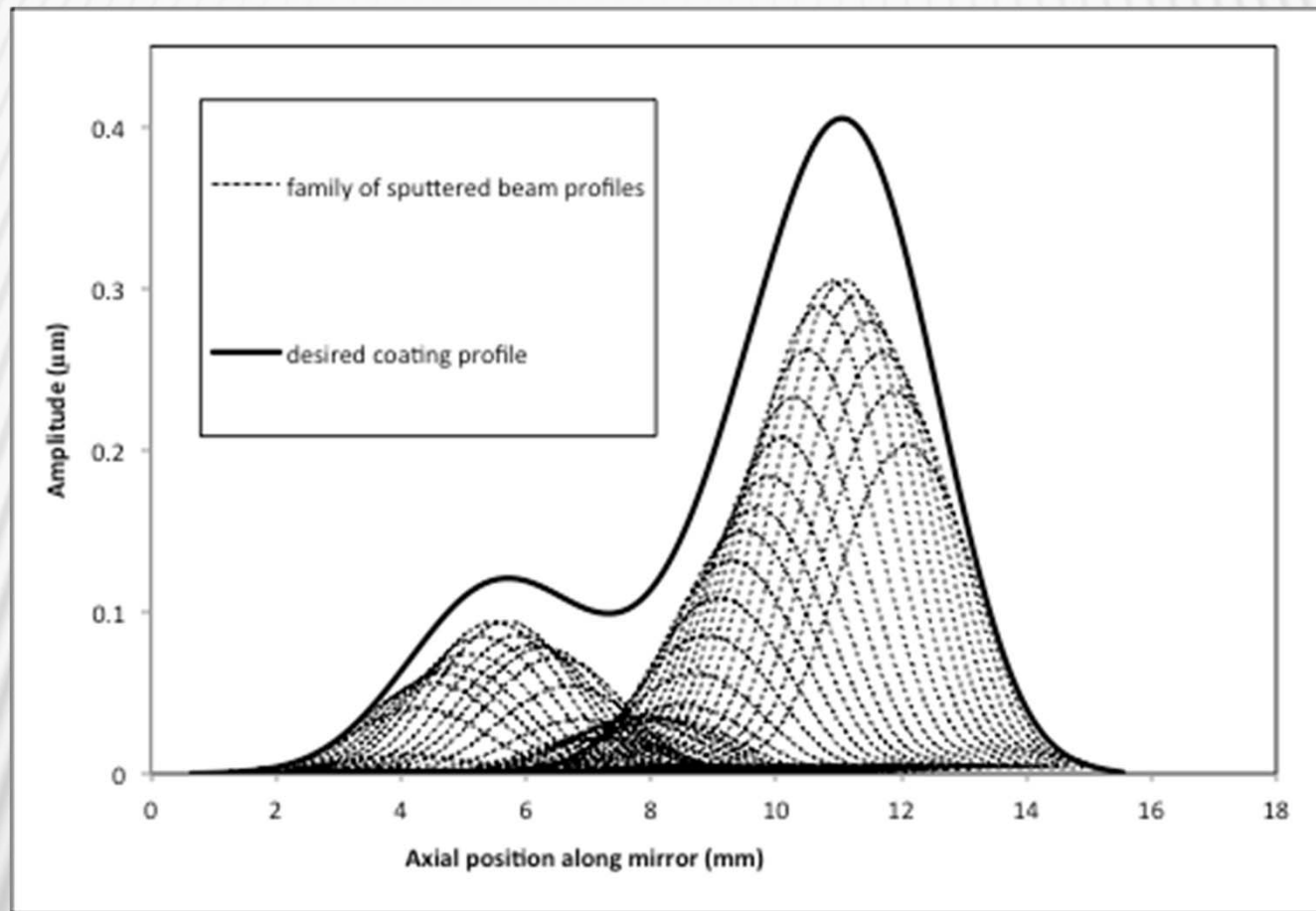
Process sequence - differential deposition



Process sequence - differential deposition



Process sequence

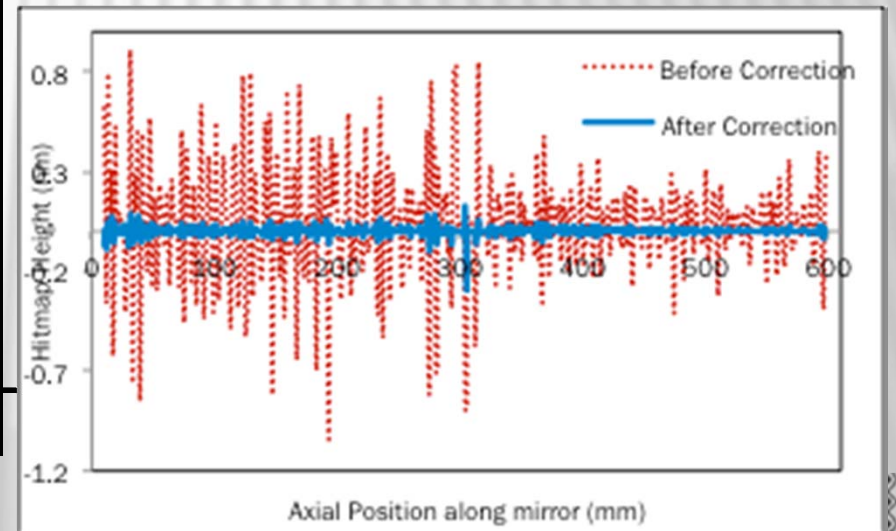
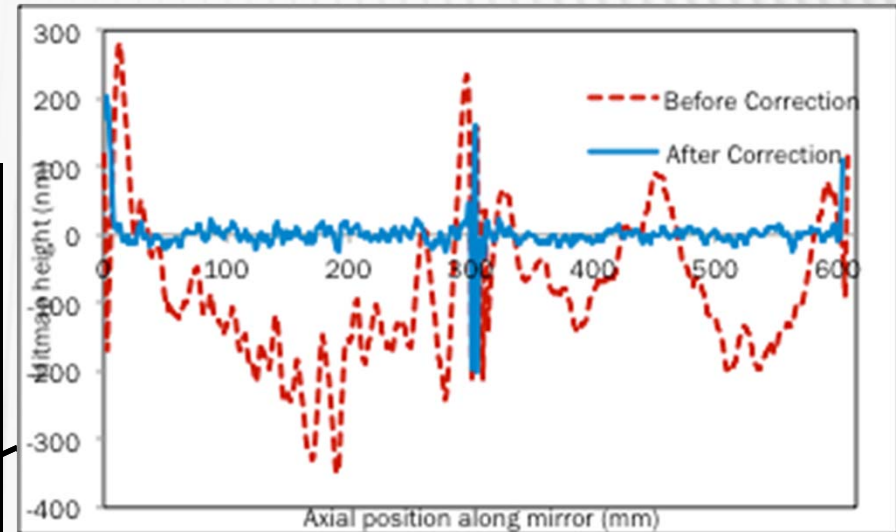




Theoretical performance improvement

Simulations performed on X-ray shell profile of 8 arc sec simulated HPD

Correction stage	Average deposition amplitude (nm)	Slit-size (mm)	Angular resolution (arc secs)
1	300	5	3.61
2	40	2	0.68
3	4	1	0.22
4	1	0.25	0.14



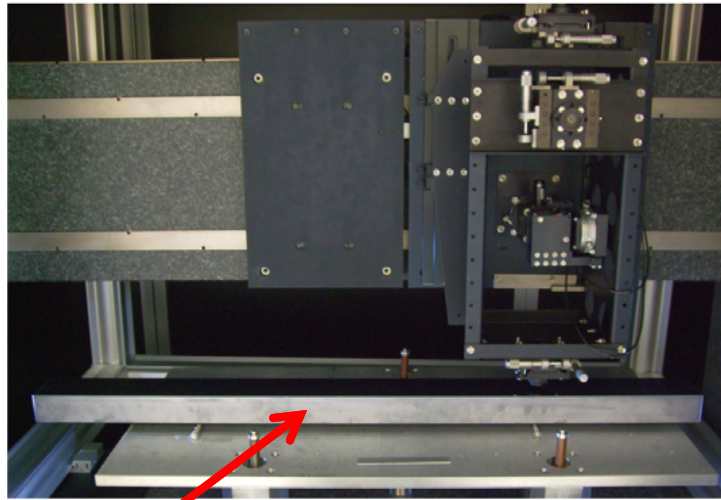


Possible practical limitations

- *Variation of sputtered beam profile along the length of mirror - particularly for short focal length mirrors*
- *Deviation in the simulated sputtered beam profile from actual profile, beam non-uniformities, etc*
- *Positional inaccuracy of the slit with respect to mirror*
- *Metrology uncertainty*
- *Stress effects*



Technique is used for synchrotron optics



Optic undergoing metrology

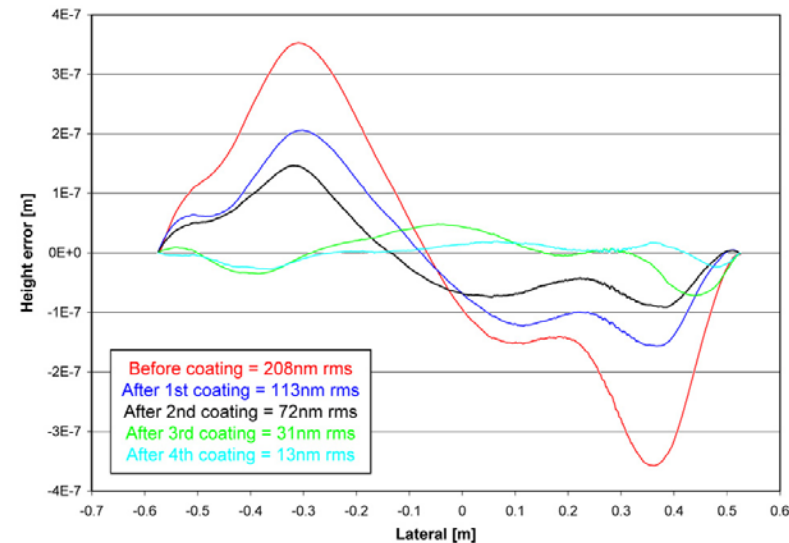
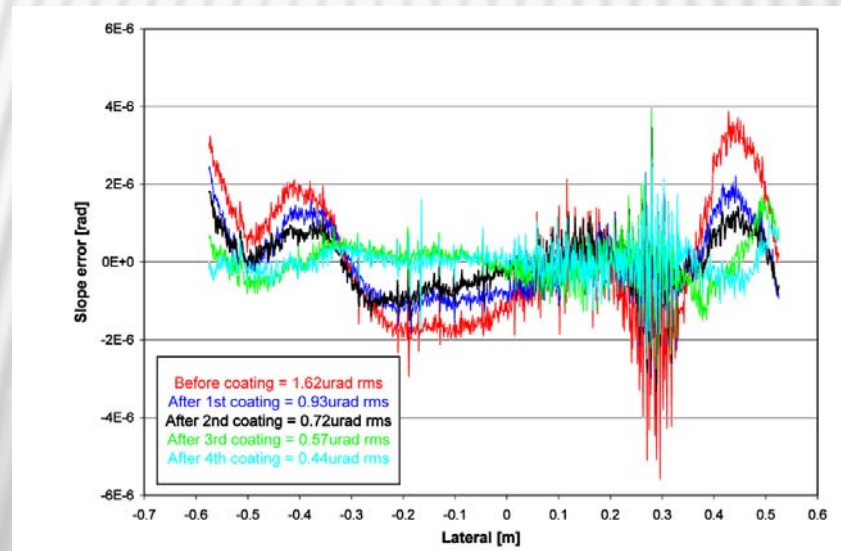


Figure errors after differential coating runs



Slope errors after differential coating runs

From:

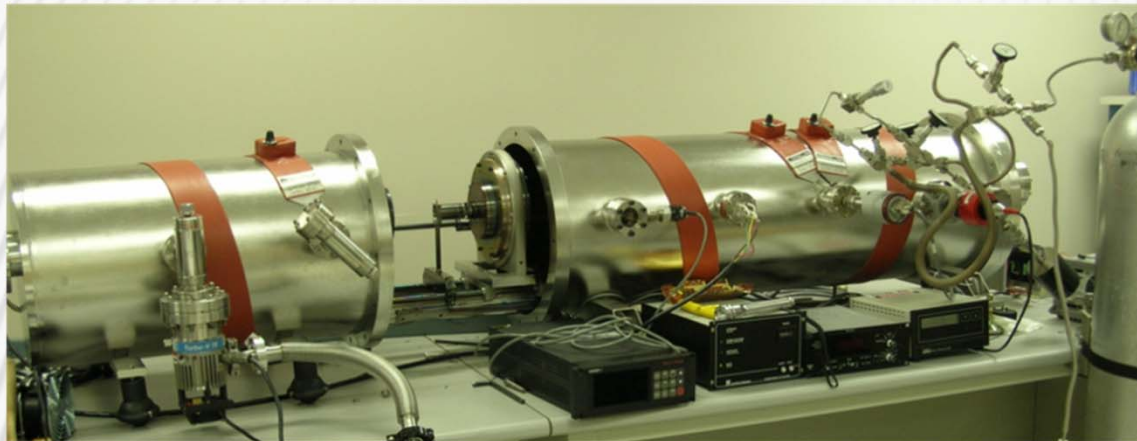
A preferential coating
 technique for fabricating
 large, high quality optics

S.G. Alcock, S. Cockerton,
 NIM A 616, 2010

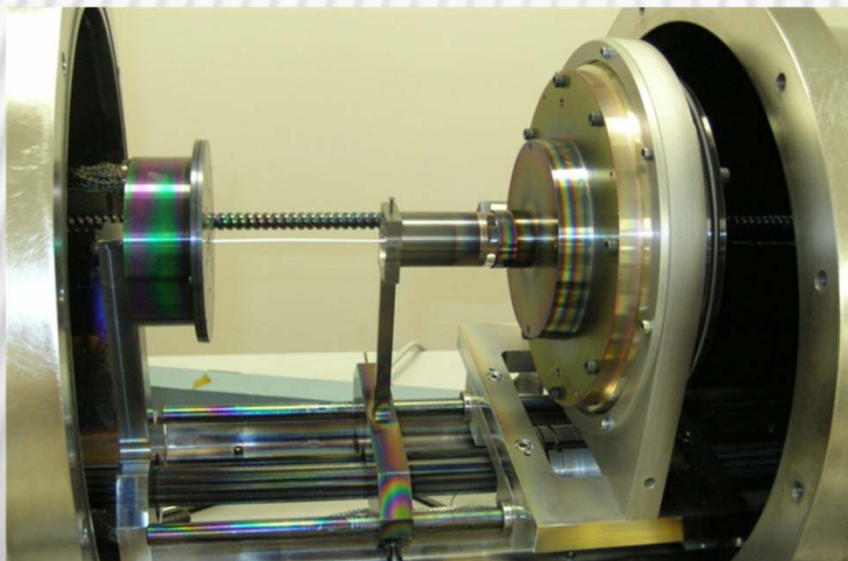




Proof of concept on full-shell optics



Modify an old coating chamber



Miniature medical optics





Proof of concept on few-cm-scale medical imaging optics

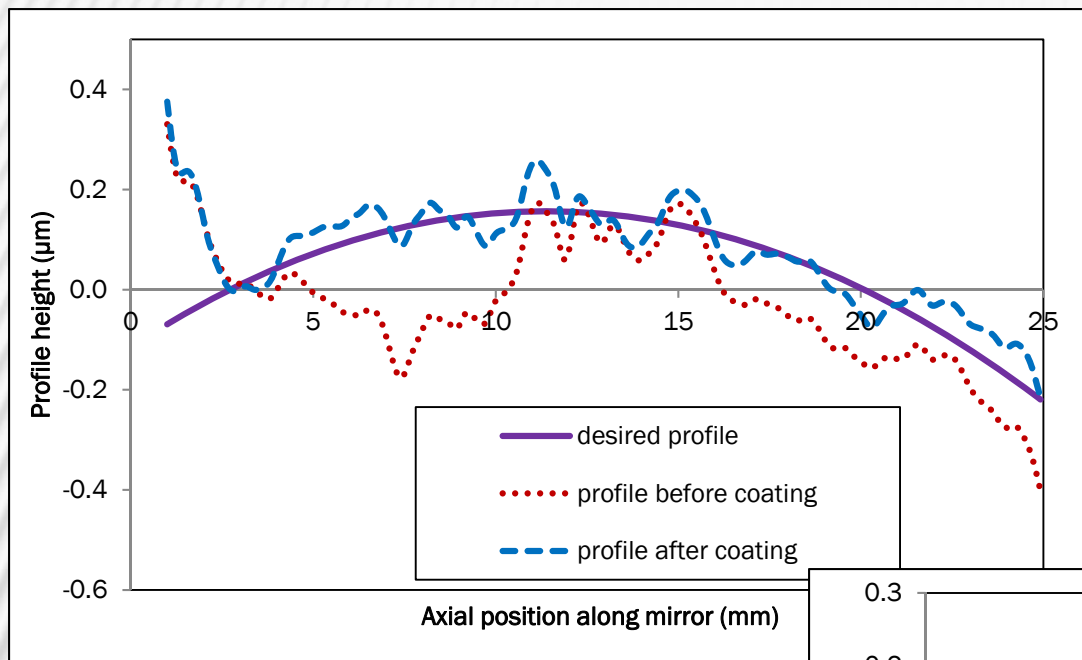
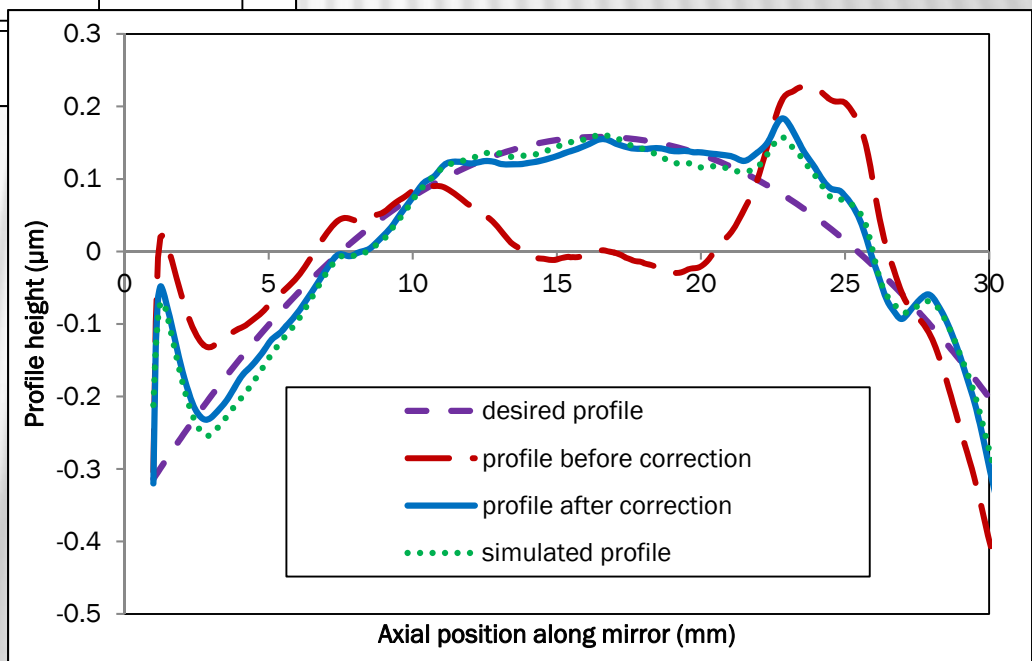


Figure error improvement from
 $0.11 \mu\text{m}$ to $0.058 \mu\text{m rms}$

Slope error improvement from
12 arc sec to 7 arc sec rms





Proof of concept on few-cm-scale medical imaging optics

*Demonstration showed that concept works for full shell optics
but effectiveness severely limited by stylus profilometer
necessary to measure inside the very small diameter medical
imaging shells*





General metrology limitation

*Simulations performed on X-ray shell of
8 arc sec simulated HPD*

Correction stage	Average deposition amplitude (nm)	Slit-size (mm)	Metrology uncertainty (nm)	Angular resolution (arc secs)
1	300	5	± 0	3.6
			± 10	3.6
			± 50	7.3
2	40	2	± 0	0.6
			± 1	1
			± 5	2
			± 10	3.5
3	4	1	± 0	0.2
			± 0.5	0.2
			± 1	0.5
			± 2	0.8

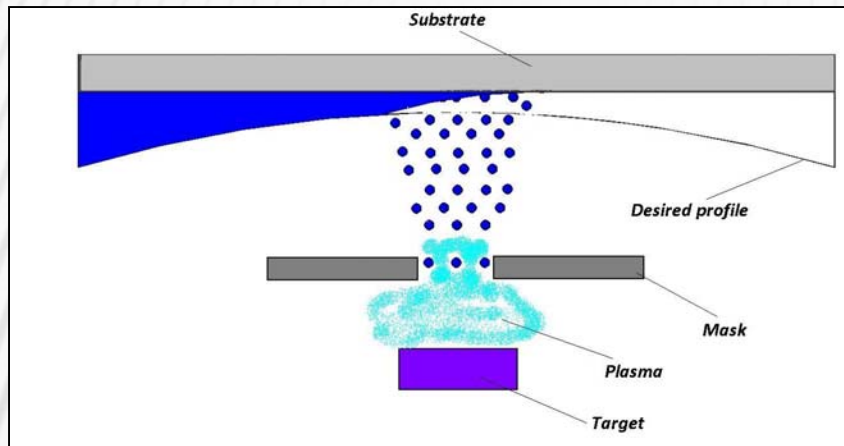
- *Potential for ~arc-second-level resolution - with MSFC's metrology equipment*
- *Sub-arc sec resolution could be possible with the state-of-art metrology equipment*



Other X-ray optics



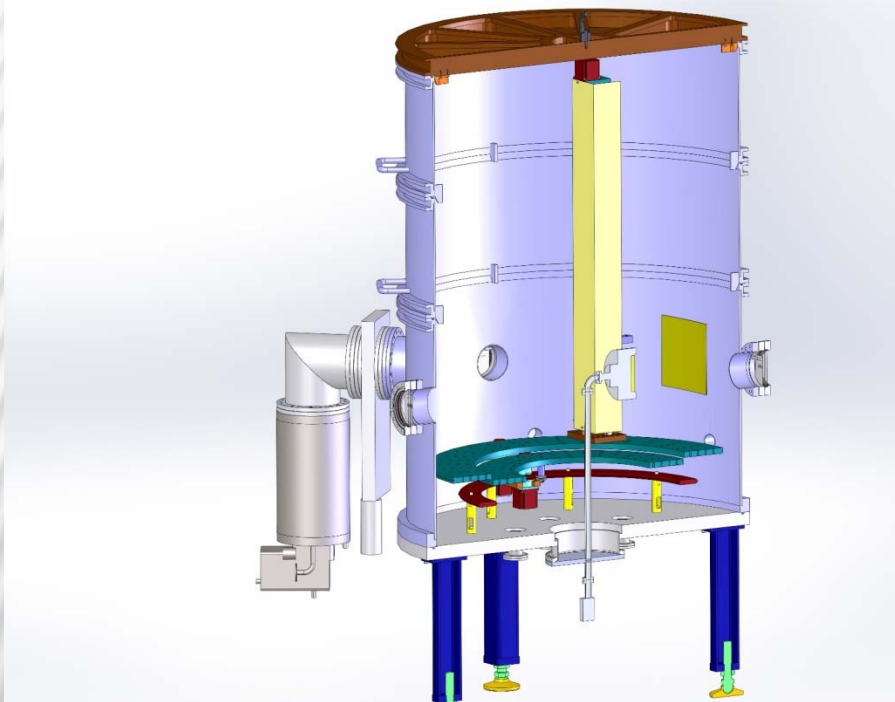
- * *Technique equally applicable to the planar geometry of segmented optics*



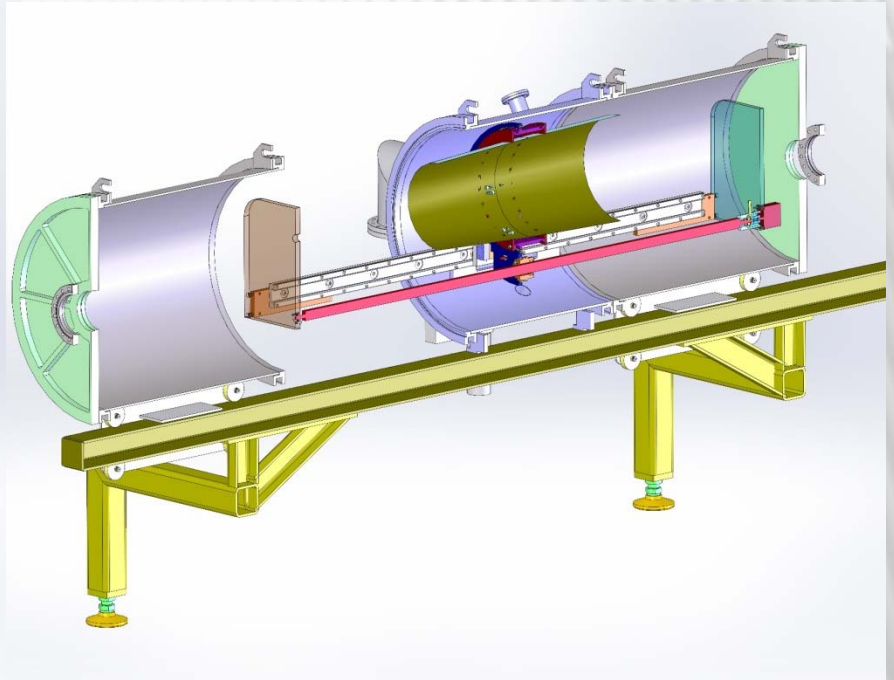
- * *Can correct deviations low-order axial-figure errors and azimuthal axial slope variations in slumped glass mirrors*



New coating systems



Vertical chamber for segmented optics

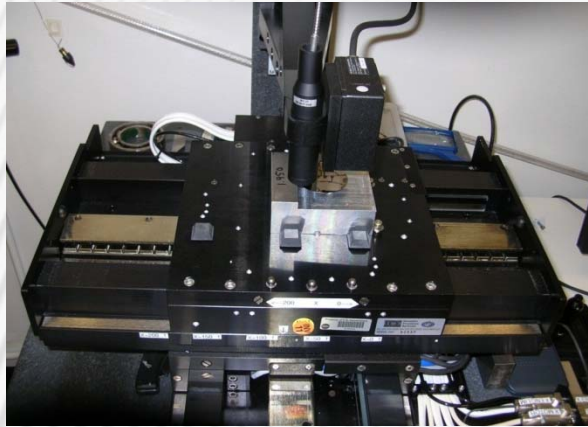


Horizontal chamber for 0.25-m-scale full shell optics

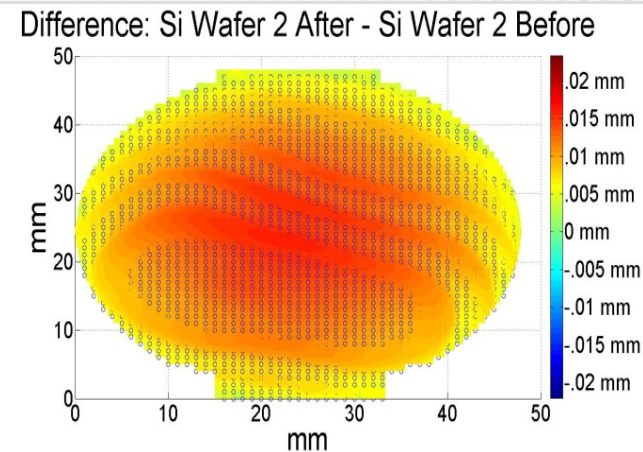




Stress measurements on silicon wafers

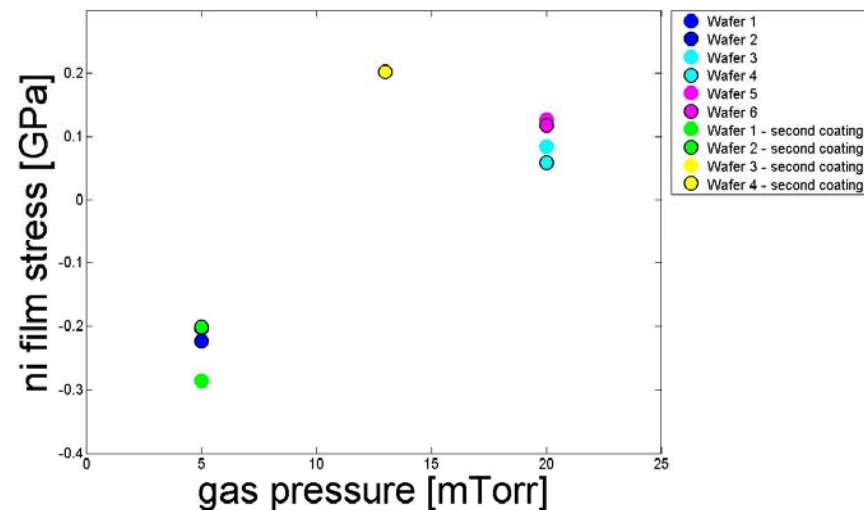


Solaris laserscan
profilometer



Deformed wafer

Experimental Stress Measurements
of Nickel Thin Films and Associated
X-ray Optic Applications
Danielle N. Gurgew
Emory University, Atlanta, GA, 30322
Intern, High Energy Astrophysics,
Marshall Space Flight Center, Emory
University.



Calculated stress





Current Status and Conclusion

- The differential deposition technique can in theory correct shell figures to ~ arcsecond value
- We have received APRA funding and are building two custom system to demonstrate the technique on full shell and segmented optics
- We hope to be able to demonstrate < 5 arcsec performance in < 2 years
- To go beyond this, (arcsecond level) is very difficult to judge as we have not yet discovered the problems.
 - May necessitate in-situ metrology, stress reduction investigations, correcting for gravity effects, correcting for temperature effects
 - Some of this will become obvious in early parts of the investigation

